Technical Memo

To: Mike Greer, City of Bismarck

From: Jeff Hruby, PE (AE2S)
Brent Erickson, PE (HDR Engineering, Inc.)

Project: City of Bismarck – Stormwater Design Standards Manual (SWDSM) Update

Subject: **TM 400 Submittal and Analysis Methodologies - DRAFT**

Date: August 29, 2016

1.0 Recommendations

The goals of the procedure recommendations are as follows:

1. Provide ease of navigating the SWDSM to determine the requirements applicable for a project; and
2. Clearly and concisely define analysis methodology requirements.

We recommend that the updated Stormwater Design Standards Manual (SWDSM) include the analysis methodology requirements as detailed in the attached draft section of the SWDSM and summarized below:

1. The following Analysis Methodology topics have been separated into individual chapters in the SWDSM (Chapters 4-7):
   a. Chapter 4 – Peak Discharge Control Compliance;
   b. Chapter 5 – Water Quality;
   c. Chapter 6 – Drainage and Conveyance; and
   d. Chapter 7 – Construction Stormwater Control.

   We based the division of chapters on the overall development design process, recognizing that projects most often begin with sizing stormwater detention facilities (Chapters 4 and 5), then proceed to the detailed site drainage design (Chapter 6), and finally end with preparing a site erosion and sediment control plan (Chapter 7).
2. The following Sections have been included with each of the chapters described above:
   a. Performance Requirements;
   b. Minimum Design Requirements; and
   c. Analysis Methodologies.

   For this technical memorandum, we have only drafted the Analysis Methodologies section for the four chapters with the intent that the other two sections would be added in TM 500 (see TM summary on the following page).

3. Each section includes a presentation of requirements and references.
    a. To accommodate future updates to data, such as rainfall, certain items have been included as References to allow for easy replacement/updating in the future. The References will likely be located in the Appendix of the final SWDSM document.
4. We are recommending that the City considers changing from 6-hour to 24-hour duration storm.
    a. Reasons to require 24-hr duration:
        i. Storm events result in a higher runoff volume;
        ii. Peak runoff may be higher than the 6-hr event in pervious areas; and
        iii. The 24-hr event is more commonly used as the design event.
5. Maximum sheet flow length is recommended to not exceed 100 feet.
    a. The current SWDSM specifies a maximum sheet flow length of 300 feet. The currently accepted maximum, however, is 100 feet.
6. We recommend that the SWDSM include tables of commonly used parameters with the values required by the City of Bismarck. Values for parameters not included in the SWDSM will be obtained from accepted literature. The literature used must then be cited or referenced within the SWDSM.
7. We recommend that all hydrology analyses be required to separate pervious and impervious land cover. This will result in more accurate runoff analysis from sites when compared to the practice of using composite CN values.
    a. A table providing typical impervious coverage of residential, commercial, and industrial areas has been included to be used when analyzing offsite drainage that is routed through a site.
8. Minimum impervious coverages have been provided in a table to be used when analyzing hydrology during the platting stage.
9. Runoff Curve Numbers (CN values) have been limited to those necessary to complete an analysis within the City of Bismarck. The following determinations were made in the creation of this table:
    a. Gravel surfaces (i.e. roadways and parking lots) shall be assigned a CN of 96.
    b. All grass, pasture, and rangeland shall be assumed as “Good” condition unless otherwise approved by the City Engineer.
        i. This was determined to be appropriate as the occurrence of ground that is not in “Good” condition is likely the result of previous alteration of the ground cover (i.e. grading, construction, etc.).
        ii. This will maintain consistency throughout SWMP submittals.
    c. Agricultural Land was summarized into a single cover type of “Cropland.”
        i. An average was taken of the many “Good” condition Cover Types found in the TR-55 Agricultural Lands table for each Hydrologic Soil Group (HSG). These averages were then used to assign CN values for Cropland in the SWDSM.

10. Typical impervious cover percentages have been provided, sourced from TR-55, for various density residential developments, commercial land use, and industrial land use.
    a. These percentages are intended to be used in the following situations:
        i. Modeling of offsite watersheds that are routed through a project site.
11. Tables presenting coefficients used in analyses have been summarized to include only those values frequently used for analysis within the City of Bismarck.
    a. This results in short, concise data tables.
    b. For situations not covered by the tables provided in the SWDSM, the design engineer will be required to use an accepted source to determine the appropriate value. The source used must be noted in the SWDSM.
12. A table of entrance and exit loss coefficients for culverts and storm sewer has been included in the SWDSM.
    a. Entrance losses within storm sewer have been broken down for "Manholes" and "Inlets – Angled Through" both of which include various bend angles.
13. Acceptable modeling software has been detailed for each of the chapters and included as References.
    a. Detailing acceptable software for various applications is intended to improve the quality of the designs while also reducing confusion among reviewers.

2.0 Project Purpose

The City of Bismarck (City) has commissioned AE2S|HDR to assist in reviewing and updating the Stormwater Design Standards Manual (SWDSM) that was originally adopted in 2000. The objective of this study (Project) is to provide the City with an updated SWDSM and recommendations for modifications to other pertinent items such as Title 14.1 of the Code of Ordinances and the City's Standard Specifications. To accomplish this objective, the Project has been split into several tasks through which a series of technical memorandums will be developed, culminating in a final updated SWDSM. Project tasks are as follows:

1. Project Management & Kick-off Meetings;
2. Title 14.1 Ordinance and MS4 Permit Review (TM 200);
3. Procedures Review and Recommendations (TM 300);
4. Analysis Methodology Review and Recommendations (TM 400);
5. Design and Performance Review and Recommendations (TM 500);
6. Stormwater, Erosion Control, and Restoration Standard Specifications and Standard Details Review and Recommendations (TM 500); and
7. Updated Stormwater Design Standards Manual.

The purpose of this document (Technical Memorandum 400) is as follows:

a. Summarize the recommended chapters and sections relating to the Analysis Methodologies as well as the resulting format, or layout;
b. Summarize the recommended changes on how information is organized; and
c. Summarize the existing Analysis Methodologies.

After review of the findings and recommendations by City staff, a final TM will be prepared incorporating comments. The recommendations of the final TM will be incorporated into the revised SWDSM.

3.0 Existing Analysis Methodologies

The existing guidance on Analysis Methodologies is provided within Chapter 3 Stormwater Hydrology of the existing SWDSM.

The existing Chapter 3 provides an extensive amount of detail into many topics relating to stormwater hydrology, many of which are not utilized in practice. This results in a 33-page document that can be an overload of information for design engineers searching for guidance on the City's desired Analysis Methodologies.

The existing SWDSM provides instruction on how to perform many of the methods described as well as detailed information that is widely available in literature and on the internet, such as Curve Numbers and Manning's n coefficients. Because it is assumed that a certain level of expertise should act as a prerequisite to using the SWDSM, many of these details and descriptions have been excluded from the recommended draft section of the SWDSM.

Attachments Draft SWDSM Chapters 4, 5, 6, and 7 – Analysis Methodologies
Analysis Methodologies References

4.0 PEAK DISCHARGE CONTROL COMPLIANCE

The goal of this Chapter is to provide guidance on the design, performance, and analysis requirements of the City of Bismarck in regard to Peak Discharge Control Compliance.

4.1 Performance Requirements

Future Section

4.2 Minimum Design Standards

Future Section

4.3 Analysis Methodologies

The goal of this Section is to provide detailed requirements for the analysis of Peak Discharge Control Compliance. This section is not intended to provide instruction on how to use the various methodologies or software packages as it is assumed that a sufficient understanding of hydrologic and hydraulic analyses as they apply to urban stormwater management and drainage is a prerequisite to the use of this manual.

4.3.1 Hydrology (Computing Runoff)

The following list is intended to provide the design engineer with the City of Bismarck requirements for computing runoff.

1. **Acceptable Methods:** NRCS (SCS) Curve Number (CN) Method & Time of Concentration Methods. The Rational Method is not an accepted methodology for Peak Discharge Control Compliance.

2. **Separation of Impervious/Pervious**: Impervious and pervious cover must be separated in the analysis.

   Example:

   If a 10-acre site is 50 percent impervious with the pervious portion having a CN of 74, the site shall not be assumed to have a single, composite CN of 86. Instead, the runoff shall be computed using a 5-acre sub-watershed with a CN of 98 and a separate 5-acre sub-watershed with a CN of 74. Both sub-watersheds shall be assigned the same Tc.

   a. Pervious and Impervious area within the project site must be manually measured to reflect the actual site design.

   b. Modeling of offsite watersheds that are routed through a project site may utilize typical impervious coverages as provided in ***Table 4-1***.

Table 4-1 *– Typical Impervious Coverage for Offsite Drainage*

Land Use Type		***Impervious Cover***
Residential Developments	1/8 Acre Lots	65%
	1/4 Acre Lots	38%
	1/3 Acre Lots	30%
	1/2 Acre Lots	25%
	1 Acre Lots	20%
	2 Acre Lots	12%
Commercial		85%
Industrial		72%

3. **Minimum Impervious Coverage:**

   a. **Plats:** Development in the platting phase shall perform hydrologic analyses based on the minimum impevious coverage provided in ***Table 4-2***.

Table 4-2 *– Minimum Impervious Coverage*

Zoning Type		***Minimum Impervious Cover***
Residential Developments	RR	12%
	RR5	12%
	R5	35%
	RMH	50%
	R10	50%
	RM	75%
	RT	75%
Commercial		85%
Industrial		90%

   b. **Site Plans:** Shall use the actual impervious cover designed.

4. **Hydrologic Soil Group (HSG):**

    a. Shall be obtained from the NRCS Web Soil Survey;

    b. Complex soil groups shall be set to the Aggregation Method of "Dominant Condition" within the Advanced Options of the NRCS Web Soil Survey (See **Reference #1**);

    c. "Urban Land" shall be assigned a HSG of "C";

    d. Split HSG classifications shall be assigned the HSG with the higher runoff potential (i.e. HSG B/D shall be assumed to be HSG D).

5. **CN Values:** CN values shall be obtained from ***Table 4-3***. Values different from those provided in ***Table 4-3*** must be approved by the City Engineer.

Table 4-3 – *Runoff Curve Numbers*

Cover Type	***Curve Numbers for HSG Soil Groups***			
	HSG A	***HSG B***	***HSG C***	***HSG D***
Impervious	98	98	98	98
Gravel Surface	96	96	96	96
Grass (Lawn)	39	61	74	80
Brush	30	48	65	73
Pasture/Rangeland	39	61	74	80
Cropland	62	73	80	84
Meadow (not grazed)	30	58	71	78

6. **Time of Concentration (Tc):**

    a. **Minimum Tc:** 5 minutes

    b. **Sheet Flow:** Maximum length of 100 feet.

7. **Rainfall Depths:** See **Reference #2**

8. **Rainfall Distribution:** SCS Unit Hydrograph Type II

9. **Rainfall Event:** 24-Hour Storm, unless otherwise master planned or platted.

10. **Maximum Time Step:** 10 minutes

11. **Gravel Roadways and Parking Lots:** Shall be considered to be impervious in the analysis.

4.3.2 Hydraulic Routing

The following list is intended to provide the Engineer with the City of Bismarck requirements for Hydraulic Routing.

1. **Routing Method:** Dynamic Routing (i.e. routing that accounts for potential backwater conditions from downstream restrictions)

2. The starting Water Surface Elevation (WSE) in a detention facility shall be assumed to be equal to the invert of the lowest engineered outlet.

3. **Infiltration as an engineered outlet:** If infiltration will be used as an engineered outlet, design engineer shall obtain City approval on approach, analysis method, and field investigation requirements as part of the scoping letter process. Additionally, all infiltration ponds within the City of Bismarck will require an underdrain.

4.3.3 Acceptable Software

Acceptable software for the analysis of peak discharge is provided by ***Reference #3***.

5.0 WATER QUALITY

The goal of this Chapter is to provide guidance on the design, performance, and analysis of the Water Quality requirements of the City of Bismarck as outlined in the City's MS4 permit (***Reference #4***).

5.1 Performance Requirements

Future Section

5.2 Minimum Design Standards

Future Section

5.3 Analysis Methodologies

The goal of this Section is to provide detailed requirements for the analysis of Water Quality performance.

5.3.1 Water Quality Volume (Vwq)

Determined using Appendix 1 of the City of Bismarck's MS4 Permit (**Reference #4**). The following is an example of computing the water quality volume for a detention facility:

Example:

Site: 40 acres, 40 percent impervious

Vwq = 1,800 cu. ft. / acre * (40 acres * 0.40) = 28,800 cu. ft.

5.3.2 Water Quality Drawdown Time

Drawdown time refers to the amount of time it takes for the Vwq to drain down to within 3 inches of the lowest engineered outlet. Depths under 0.25 feet (3 inches) may take an extensive amount of time to drawdown to the point of zero volume due to minimal head.

For the purposes of determining compliance with the drawdown time requirements, the method presented in **Reference #5** shall be used.

5.3.3 Alternate Methodology

In situations not clearly covered by Appendix 1 of the MS4 Permit, such as multiple basins in series, alternate methodologies that explicitly model the build-up, wash-off, and trapping of Total Suspended Solids (TSS) may be applied as determined acceptable by the City in the scoping letter.

1. When using alternate methodologies, 80% TSS removal on an average annual basin shall be achieved.

2. **Example Alternate Methodologies:**

   Example alternate methodologies are provided in ***Reference #6***.

6.0 DRAINAGE AND CONVEYANCE

The goal of this Chapter is to provide guidance on the design, performance, and analysis requirements for Drainage and Conveyance within the City of Bismarck. Examples of drainage and conveyance facilities include storm sewer, drainage ditches, streets, open channels, culverts and other engineered systems intended to carry stormwater to a Point of Discharge.

6.1 Performance Requirements

Future Section

6.2 Minimum Design Standards

Future Section

6.3 Analysis Methodologies

The goal of this Section is to provide the detailed requirements for the analysis of drainage and conveyance facilities.

6.3.1 Hydrologic Analysis

1. Methods discussed in Chapter 4 of the SWDSM.

2. **Rational Method**

    a. Intensity-Duration-Frequency (IDF) curves shall be from NOAA Atlas 14 using the Bismarck Municipal Airport station (***Reference #7***).

    b. Intensity (I) shall be based on the Time of Concentration (Tc) to the inlet(s). Note that multiple intensities may be needed for a single system.

    c. Runoff Coefficient (C) shall be determined based on the site cover and obtained from accepted literature. The source used to obtain the Runoff Coefficient(s) shall be stated in the SWMP.

6.3.2 Hydraulic Analysis

1. **Inlet Analysis:** Shall use the following methods:

    a. On-Grade:

        i. HEC-22 methodology.

    b. Sag (Low Point):

        i. HEC-22 methodology; and
        ii. Orifice/Weir Equation.

2. **Manning's n Coefficients:** Manning's n coefficients for commonly used materials and surfaces are provided in ***Table 6-1***. For surfaces not covered by ***Table 6-1***, values shall be obtained from accepted literature. The source(s) used to determine any coefficient(s) not provided in ***Table 6-1*** shall be stated in the SWMP.

Table 6-1 *– Manning's Coefficients*

Material/Surface	*Manning's n Coefficient*
RCP	0.013 – 0.014
CMP	0.022 – 0.024
HDPE (smooth)	0.010 – 0.012
HDPE (corrugated)	0.021 – 0.023
PVC	0.010 – 0.012
Vegetated Channel (not mowed)	0.035 – 0.050
Maintained Ditch/Channel (mowed)	0.030 – 0.040
Concrete Channel	0.015
Street (Asphalt)	0.014 – 0.016
Street (Concrete)	0.013 – 0.015
Urban Overland	0.045
Rural Overland	0.060

3. **Entrance and Exit Coefficients:** Entrance and Exit Coefficients for common applications are provided in ***Table 6-2***. For situations not covered by ***Table 6-2***, values should be obtained from accepted literature. The source(s) used to determine any coefficient(s) not provided in ***Table 6-2*** shall be stated in the SWMP.

Table 6-2 – *Entrance and Exit Coefficients*

	Material	*Design Scenario*	*Entrance Coefficient*	*Exit Coefficient*
Pipe or Arch Culverts	RCP	Flared End Section	0.5	1.0
		Square Cut*	0.5	
		Socket or Rounded*	0.2	
	CMP or HDPE	Projecting	0.9	
		Mitered	0.7	
		Conforms to Fill	0.5	
Box Culverts	RCP	No Wingwalls	0.5	1.0
		Wingwalls (30° - 75°)	0.4	
		Wingwalls (10° - 25°)	0.5	
Storm Sewer Inlet - Angled Through	N/A	0° (Straight Run)	0.5	N/A
		22.5°	0.7	
		45°	1.1	
		60°	1.2	
		90°	1.5	
Storm Sewer Manhole	N/A	0° (Straight Run)	0.1	N/A
		22.5°	0.4	
		45°	0.7	
		60°	0.8	
		90°	1.0	

*Applies to Headwall or Projecting.

4. **Inlet Analysis Clogging Factor:** When analyzing inlets, clogging factors must be accounted for. See ***Table 6-3***, below.

Table 6-3 – *Inlet Capacity Reduction Factors*

Inlet Type	*Location*	*Reduction Factor*	*Effective Opening*
Combination (Grate & Curb Opening)	Continuous Grade	10%	90%
	Sag (Low Point)	20%	80%
Curb Opening	Continuous Grade	20%	80%
	Sag (Low Point)	20%	80%
Grate Only	Continuous Grade	25%	75%
	Sag (Low Point)	35%	65%

6.3.3 Acceptable Drainage and Conveyance Models

*See **Reference #8**.*

7.0 CONSTRUCTION STORMWATER CONTROL

The goal of this chapter is to provide guidance on the design, performance, and analysis of the Construction Stormwater Control requirements of the City of Bismarck.

7.1 Performance Requirements

Future Section

7.2 Minimum Design Standards

Future Section

7.3 Analysis Methodologies

The goal of this section is to provide specific analysis methodologies for Construction Stormwater Management as required by the North Dakota Construction General Permit and the City's MS4 General (***Reference #9***).

7.3.1 Hydrology (Computing Runoff)

1. Runoff calculation methods shall be consistent with those discussed in Chapter 4.
2. **Newly Graded Ground:** A minimum CN of 90 shall be used for all newly graded ground regardless of Hydrologic Soil Group.

7.3.2 Hydraulic Analysis

Hydraulic analyses shall be made using the methods described below unless otherwise approved by the City Engineer.

1. **Velocity:** Shall be obtained using one of the acceptable methods presented in ***Reference #8.***
2. **Shear Stress:** Shall be calculated using the following equation:

   $$\tau = \rho \, g \, R \, S$$

   Where,

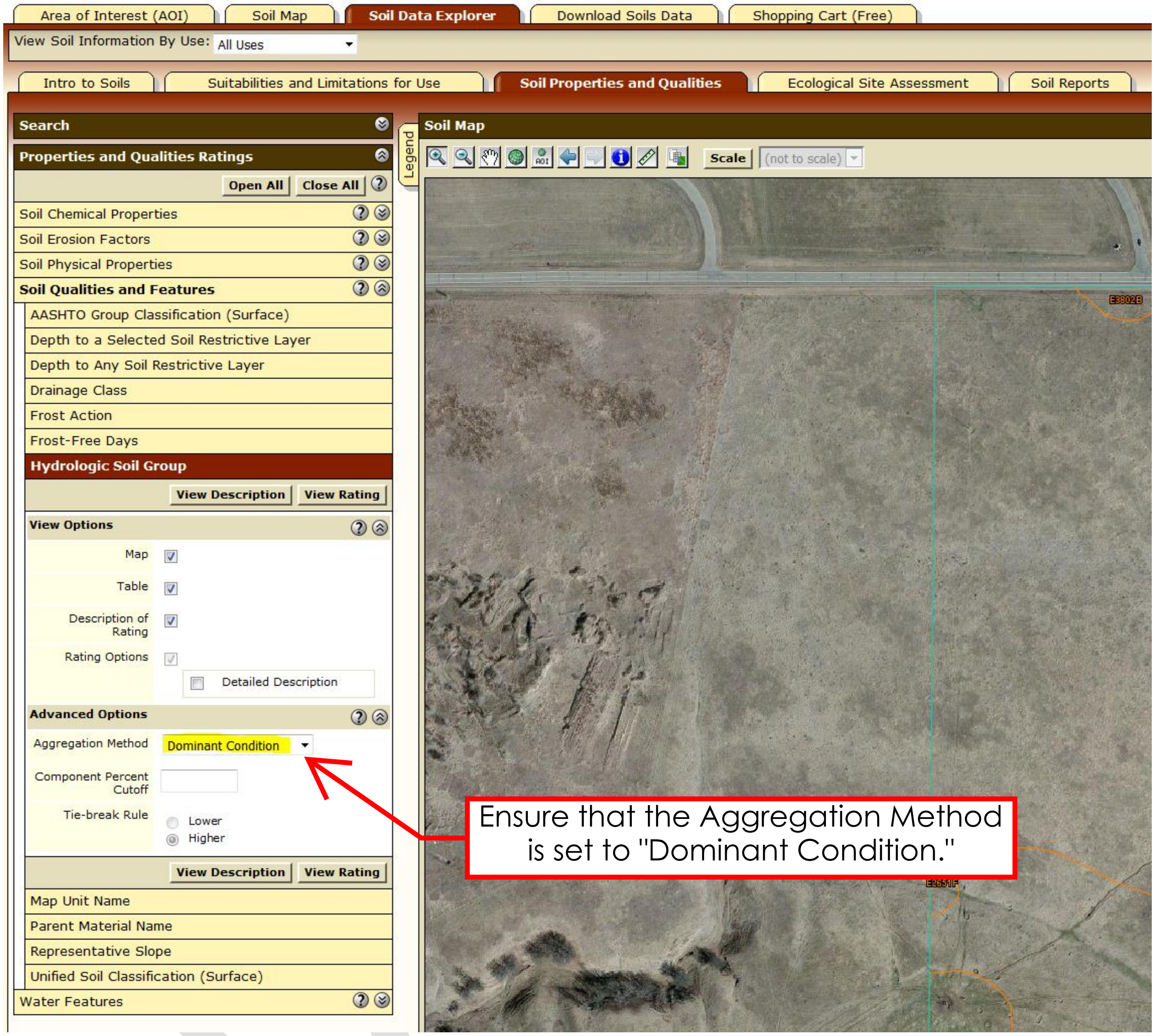
   τ = Shear Stress (N)
   ρ = Density of Water (kg/m^3)
   g = Acceleration Due to Water (9.81 m/s^2)
   R = Hydraulic Radius
   S = Surface Water Slope (Energy Grade Line)

3. **Capacity of Swales and Ditches:** Shall be analyzed using one of the methods presented in ***Reference #8***.

ANALYSIS METHODOLOGIES REFERENCES

Effective Date: _____________

REFERENCE #1 – NRCS WEB SOIL SURVEY AGGREGATION METHOD



Source: http://websoilsurvey.sc.egov.usda.gov/

REFERENCE #2 – ATLAS 14 RAINFALL DEPTHS

Average Recurrence Frequency	24-Hour Rainfall Event (inches)
2-Year (50% Chance Storm)	2.1
5-Year (20% Chance Storm)	2.6
10-Year (10% Chance Storm)	3.1
100-Year (1% Chance Storm)	5.3

Source: http://www.noaa.gov/

REFERENCE #3 – ACCEPTABLE SOFTWARE FOR HYDROLOGIC ANALYSIS

The following software is recommended for the analysis of peak discharge. The City acknowledges that other software exists and that new software may become available in the future. As such, software requests may be made in the scoping letter for review and request for City approval.

1. HydroCAD
2. InfoSWMM
3. XP-SWMM / XP-STORM
4. Storm & Sanitary Analysis (SSA)
5. Bentley CivilStorm
6. Civil 3D Hydrographs
7. HEC-HMS

Note that because EPA-SWMM uses a different Curve Number methodology, it is not recommended for use in determining compliance with the SWDSM.

REFERENCE #4 – APPENDIX 1 MS4 PERMIT

Control	Water Quality Design Consideration
Wet Detention Ponds	Water Quality Volume (Vwq) = 1800 cu-ft per impervious acre draining to the pond. The drawdown time for the Vwq should be a minimum of 12 hours.
Dry Detention Ponds (w/Extended Detention)	Extended Detention / Water Quality Volume (Vwqed) = 1800 cu-ft per impervious acre draining to pond. The drawdown time for the Vwqed should be a minimum of 24 hours and not more than 72 hours.
Infiltration	Water Quality Volume (Vwq) = 0.5 inches from impervious area. The volume captured in rain gardens, or passed through biofilters with under drains, would be grouped with infiltration for water quality treatment. The Vwq should discharge through the soil or filter media within 48 hours. Additional flows that cannot be infiltrated in 48 hours should be routed to bypass the system through a stabilized outlet.
Flow-Through Treatment Devices	Size devices to treat the first 0.5 inches of runoff from impervious area.
Redevelopment / Retrofit	Incorporate water quality criteria by reducing impervious surface area and implementing controls to treat the first 0.5 inches of runoff from impervious areas.

Source: https://www.ndhealth.gov/

REFERENCE #5 – WATER QUALITY DRAWDOWN TIME COMPLIANCE

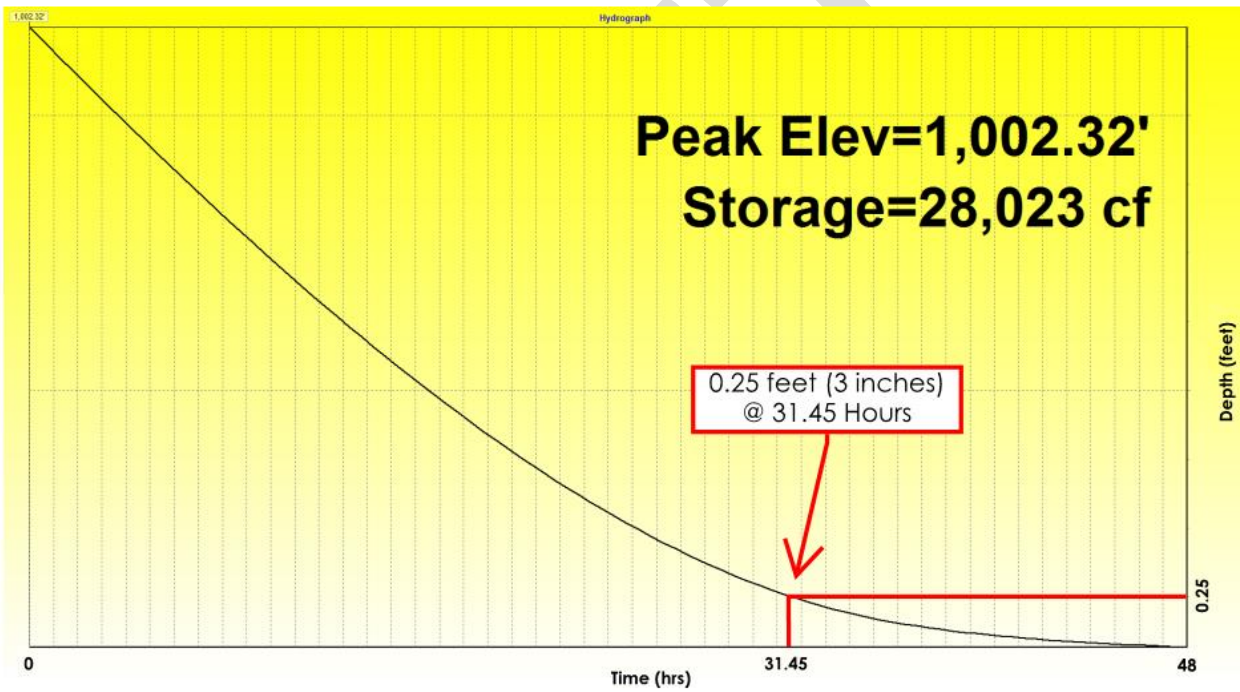
Example:

Dry Detention Basin: 100’ by 100’ at lowest engineered outlet (basin floor), 4H:1V side slopes.

Depth for Vwq is 2.32’ corresponding to approximately 28,800 cu. ft. in basin.

Set initial depth in the basin to 2.32’ with zero rainfall / runoff entering the basin.

The drawdown time to within 0.25 feet (3 inches) of the basin floor is greater than 24 hours and less than 72 hours, so the basin meets water quality performance.



Time (hours)	Inflow (cfs)	Storage (cubic-feet)	Elevation (feet)	Primary (cfs)
31.30	0.00	2,652	1,000.26	0.09
31.35	0.00	2,637	1,000.26	0.09
31.40	0.00	2,621	1,000.26	0.09
31.45	0.00	2,606	1,000.25	0.09
31.50	0.00	2,591	1,000.25	0.08
31.55	0.00	2,575	1,000.25	0.08
31.60	0.00	2,560	1,000.25	0.08
31.65	0.00	2,545	1,000.25	0.08
31.70	0.00	2,530	1,000.25	0.08
31.75	0.00	2,515	1,000.25	0.08
31.80	0.00	2,500	1,000.24	0.08

0.25' Depth (Invert = 1,000)

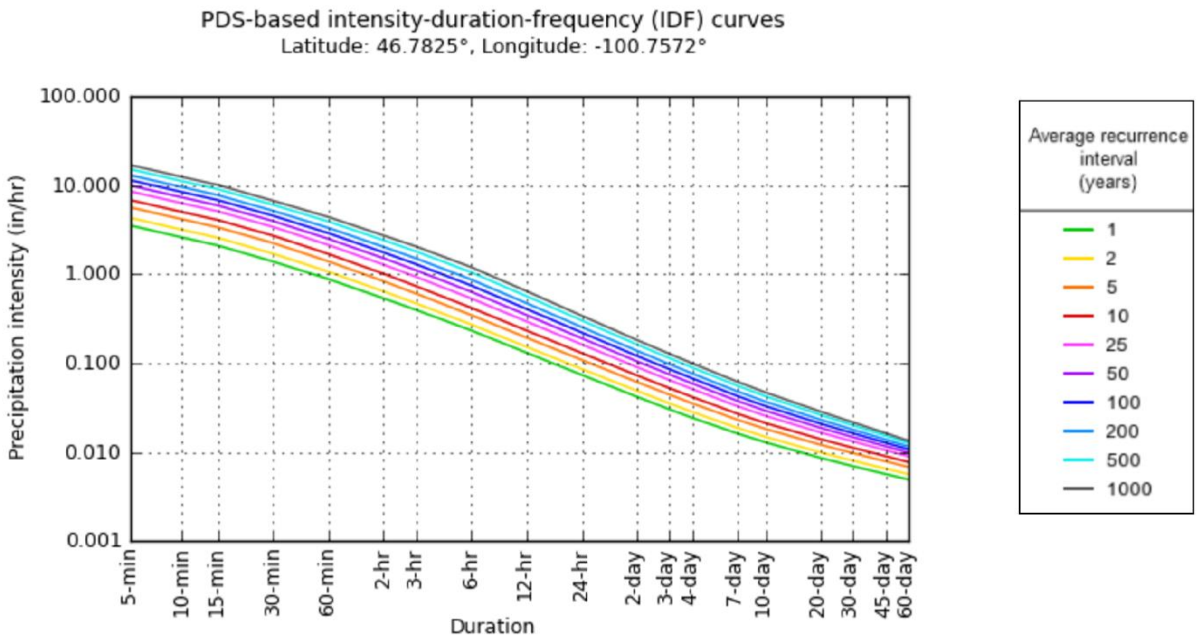
REFERENCE #6 – WATER QUALITY ALTERNATE METHODOLOGIES

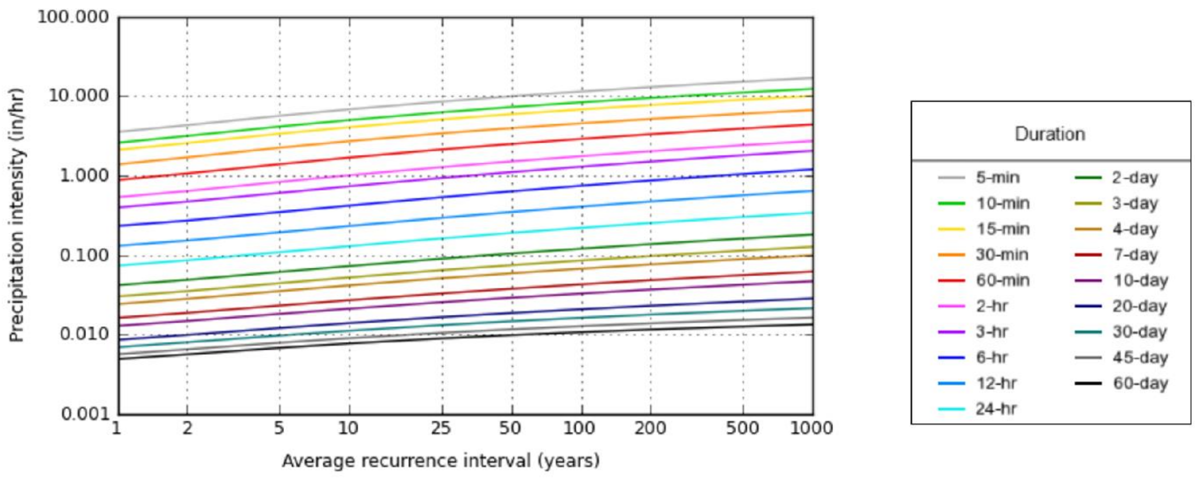
The following are examples of alternate methodologies for analyzing water quality performance.

1. P8 Urban Catchment Model, SLMM, SWMM, etc.
2. Source Loading and Management Model (SLAMM)
3. Water Quality Analysis Simulation Program (WASP)
4. Storm Water Management Model (SWMM)

REFERENCE #7 – BISMARCK IDF CURVES

Precipitation-Intensity Graphical





NOAA Atlas 14, Volume 8, Version 2

Source: http://www.noaa.gov/

Precipitation-Intensity Tabular

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches/hour)[1]										
Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	3.54 (3.01-4.20)	4.31 (3.67-5.12)	5.65 (4.80-6.74)	6.83 (5.75-8.18)	8.56 (6.94-10.7)	9.96 (7.84-12.7)	11.4 (8.62-14.9)	13.0 (9.29-17.5)	15.2 (10.3-21.0)	16.9 (11.1-23.7)
10-min	2.59 (2.21-3.07)	3.16 (2.69-3.76)	4.14 (3.51-4.93)	5.00 (4.21-5.99)	6.26 (5.08-7.86)	7.29 (5.74-9.27)	8.37 (6.31-10.9)	9.52 (6.80-12.8)	11.1 (7.57-15.4)	12.4 (8.15-17.3)
15-min	2.10 (1.80-2.50)	2.56 (2.19-3.05)	3.36 (2.85-4.01)	4.06 (3.42-4.87)	5.09 (4.13-6.39)	5.93 (4.66-7.54)	6.80 (5.12-8.88)	7.74 (5.53-10.4)	9.04 (6.16-12.5)	10.1 (6.63-14.1)
30-min	1.39 (1.18-1.65)	1.70 (1.45-2.02)	2.24 (1.90-2.67)	2.71 (2.29-3.25)	3.40 (2.76-4.26)	3.96 (3.11-5.03)	4.54 (3.42-5.92)	5.16 (3.69-6.93)	6.02 (4.10-8.32)	6.69 (4.41-9.37)
60-min	0.881 (0.751-1.05)	1.07 (0.908-1.27)	1.39 (1.18-1.66)	1.69 (1.42-2.02)	2.13 (1.73-2.69)	2.50 (1.97-3.19)	2.89 (2.18-3.79)	3.31 (2.37-4.47)	3.91 (2.67-5.43)	4.39 (2.89-6.15)
2-hr	0.534 (0.458-0.630)	0.640 (0.548-0.757)	0.833 (0.710-0.988)	1.01 (0.856-1.20)	1.28 (1.05-1.61)	1.51 (1.20-1.92)	1.76 (1.33-2.29)	2.02 (1.46-2.72)	2.41 (1.66-3.32)	2.72 (1.80-3.78)
3-hr	0.397 (0.342-0.467)	0.470 (0.404-0.553)	0.606 (0.518-0.715)	0.734 (0.624-0.871)	0.934 (0.772-1.18)	1.11 (0.884-1.41)	1.30 (0.990-1.69)	1.50 (1.09-2.02)	1.80 (1.25-2.49)	2.05 (1.36-2.84)
6-hr	0.233 (0.201-0.272)	0.272 (0.235-0.318)	0.347 (0.298-0.406)	0.419 (0.358-0.493)	0.534 (0.444-0.669)	0.634 (0.510-0.802)	0.745 (0.574-0.967)	0.869 (0.635-1.16)	1.05 (0.730-1.44)	1.20 (0.802-1.65)
12-hr	0.131 (0.114-0.152)	0.152 (0.132-0.177)	0.193 (0.167-0.225)	0.232 (0.200-0.272)	0.294 (0.246-0.366)	0.348 (0.281-0.436)	0.407 (0.315-0.523)	0.472 (0.347-0.625)	0.567 (0.397-0.771)	0.645 (0.435-0.882)
24-hr	0.074 (0.064-0.085)	0.086 (0.075-0.099)	0.109 (0.094-0.126)	0.130 (0.112-0.151)	0.162 (0.136-0.199)	0.190 (0.154-0.236)	0.221 (0.171-0.281)	0.254 (0.188-0.333)	0.302 (0.213-0.407)	0.341 (0.231-0.463)
2-day	0.042 (0.037-0.048)	0.049 (0.043-0.056)	0.061 (0.053-0.070)	0.073 (0.063-0.084)	0.090 (0.076-0.109)	0.105 (0.085-0.129)	0.120 (0.094-0.152)	0.137 (0.102-0.179)	0.162 (0.115-0.216)	0.181 (0.124-0.245)
3-day	0.030 (0.027-0.034)	0.035 (0.031-0.040)	0.044 (0.039-0.051)	0.052 (0.045-0.060)	0.064 (0.054-0.078)	0.075 (0.061-0.091)	0.085 (0.067-0.107)	0.097 (0.072-0.126)	0.114 (0.081-0.151)	0.127 (0.087-0.171)
4-day	0.024 (0.021-0.028)	0.028 (0.025-0.032)	0.035 (0.031-0.040)	0.042 (0.036-0.048)	0.051 (0.043-0.061)	0.059 (0.048-0.072)	0.067 (0.053-0.084)	0.076 (0.057-0.098)	0.089 (0.063-0.118)	0.099 (0.068-0.133)
7-day	0.016 (0.014-0.018)	0.019 (0.017-0.021)	0.023 (0.020-0.026)	0.027 (0.024-0.031)	0.033 (0.028-0.039)	0.038 (0.031-0.046)	0.043 (0.034-0.053)	0.048 (0.036-0.062)	0.056 (0.040-0.074)	0.062 (0.043-0.083)
10-day	0.013 (0.011-0.014)	0.015 (0.013-0.017)	0.018 (0.016-0.021)	0.021 (0.019-0.024)	0.026 (0.022-0.030)	0.029 (0.024-0.035)	0.033 (0.026-0.041)	0.037 (0.028-0.047)	0.042 (0.030-0.056)	0.047 (0.033-0.062)
20-day	0.009 (0.008-0.010)	0.010 (0.009-0.011)	0.012 (0.011-0.014)	0.014 (0.012-0.016)	0.017 (0.014-0.019)	0.019 (0.015-0.022)	0.021 (0.017-0.025)	0.023 (0.017-0.029)	0.026 (0.019-0.034)	0.028 (0.020-0.038)
30-day	0.007 (0.006-0.008)	0.008 (0.007-0.009)	0.010 (0.009-0.011)	0.011 (0.010-0.013)	0.013 (0.011-0.015)	0.015 (0.012-0.017)	0.016 (0.013-0.020)	0.018 (0.014-0.022)	0.020 (0.014-0.026)	0.022 (0.015-0.028)
45-day	0.006 (0.005-0.006)	0.007 (0.006-0.007)	0.008 (0.007-0.009)	0.009 (0.008-0.010)	0.010 (0.009-0.012)	0.012 (0.010-0.014)	0.013 (0.010-0.015)	0.014 (0.011-0.017)	0.015 (0.011-0.020)	0.016 (0.012-0.021)
60-day	0.005 (0.004-0.005)	0.006 (0.005-0.006)	0.007 (0.006-0.008)	0.008 (0.007-0.009)	0.009 (0.008-0.010)	0.010 (0.008-0.011)	0.011 (0.009-0.013)	0.012 (0.009-0.014)	0.013 (0.009-0.016)	0.013 (0.009-0.017)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

Source: http://www.noaa.gov/

REFERENCE #8 – ACCEPTABLE DRAINAGE AND CONVEYANCE MODELS

Acceptable Drainage & Conveyance Models

Software	***Drainages and Conveyances***		
	Storm Sewer	***Culverts***	***Open Channel & Streets***
HydroCAD	✓*	✓	✓**
InfoSWMM	✓	✓	✓
XP-SWMM/XP-STORM	✓	✓	✓
Storm and Sanitary Analysis (SSA)	✓	✓	✓
Bentley CivilStorm	✓	✓	✓
Civil 3D Storm Sewer	✓		
Civil 3D Express		✓	✓**
HY8		✓	
HEC-RAS		✓	✓
Manning's "n" Equation			✓**

* Only applicable if inlets are located at a low point or sag and the storm sewer has minimal surcharging.
**Only allowed when backwater conditions are not present.

REFERENCE #9 – ND CONSTRUCTION GENERAL PERMIT REQUIREMENTS

Appendix 1 – Erosion and Sediment Control Requirements
Requirements for designing, implementing and maintaining erosion and sediment controls.

A. Erosion and Sediment Control Practices

1. Sites using temporary (or permanent) sediment basins must meet the following requirements:

   a. Sediment basins shall be designed for a calculated volume of runoff from a 2-year, 24-hour storm per acre drained to the basin and provides not less than 1,800 cubic feet of sediment storage below the invert of the outlet pipe from each acre drained to the basin; or

   b. Basins shall be sized to provide 3,600 cubic feet of sediment storage below the invert of the outlet pipe per acre drained to the basin if calculations are not performed.

   c. Basin outlets must be designed to avoid short-circuiting and the discharge of floating debris. Basins must be designed with the ability to allow complete basin drawdown for maintenance activities. Basins must release the storage volume in at least 24 hours. Outlet structures must be designed to withdraw water from the surface, unless not practicable. If not practicable, rationale must be provided in the SWPPP. The basin must have a stabilized emergency overflow to prevent failure of pond integrity. Energy dissipation must be provided for the basin outlet.

Source: https://www.ndhealth.gov/